NUMERICAL ANALYSIS OF WIND LENSE TURBINE

ATUL CHOUDAHRY[1], BILAL MERCHANT[2], OWAIS FAROOQUI[3], ABDUL KARIM KHAN[4], UMAIR MAULANA[5]

[1]Assistant Professor, Department of Mechanical Engineering, ARMIET, Thane, M.H., India,

[2345]UG Student, Department of Mechanical Engineering, ARMIET, Thane, M.H., India,

Abstract: This Reasearch paper investigates the effect of wind lense which is shrouded diffuser with brim ring at the outlet. The purpose of adding this diffuser-ring configuration is to increase the extractable power of the wind approaching the wind turbine. The essential concept used is enhancing the possibility of the free stream velocity at the rotor in order to extract much larger power by increased velocity at the rotor. This is due to a low-pressure region behind the brim, due to a strong vortex formation, which drew more mass flow to the wind turbine inside the diffuser shroud. A computational study has been carried out in order to assess the effect of brim size and position of the throat on the increase in velocity of the wind.

Index Terms: Wind Turbine, Wind Lense, diffuser, Brim, Power Augmentation.

I. INTRODUCTION

Wind energy has gained a wide acceptance as a renewable source because of its ease of availability and improvement in the wind turbine technologies. However, there are limitations for extracting power from wind. These limitations include availability of gust at required pace throughout the day and year, diameter of the rotor and associated structural problems, safety and maintenance, etc. According to Betz, under ideal conditions, a maximum of 59% of wind energy can be extracted from a given stream tube. This limit is known as Betz limit.

Wind power generation is proportional to the wind speed cubed. Therefore, a large increase in output is brought about if it is possible to create even a slight increase in the velocity of the approaching wind to a wind turbine. If we can increase the wind speed by utilizing the fluid dynamic nature around a structure or topography, namely if we can concentrate the wind energy locally, the power output of a wind turbine can be increased substantially. Increasing diameter twice will increase power by four fold. However larger the diameter, more will be the structural and balancing problems associated with it. Hence there is a limitation on the maximum Diameter. The other way to increase power output is to increase the wind velocity through the rotor. It is evident from the power equation that twice the increase in wind velocity will increase the power output by eight times.

A shroud like structure placed around a wind turbine in order to increase mass flux through it and thereby increasing velocity of air locally. This concept was first introduced by Yuji Ohya of Kyushu university, Japan[1]. According to them, acclimation of shroud over a wind turbine enhanced its power output by almost
2-5 times. The shroud around the wind turbine concentrates the air flow on to the rotor and hence called as “wind lense” shown in Figure 1. They also have installed such power plants. According to their study, vortices induce additional flow through the rotor. This type of adaptation is suitable for a wind turbine of reasonable size as the structural design complexities are of a vital consideration. Wind lense on a larger turbine will lead to very high stresses being induced in the supporting tower.

Figure : 1 Wind Lense

The size of a wind rotor required to produce given amount of power reduces considerably because of wind lense. The other advantages include ease of installation, lower noise, brim based yaw control, etc.

In this paper, we have focused on vortices formed due to the height of brim in a Wind-Lense turbine and the position of throat of the wind lense affecting the wind speed. Therefore, we conducted numerical simulations of the flow around a Wind -Lense, paying special attention to the behavior of the vortices formed behind the brim. It was also our curiosity to find out the variation of wind speed due to change of throat position of the wind lense. The variations in maximum velocity were studied based on the ratio of brim height to throat diameter as a parameter.

II. ABOUT THE ‘WIND LENSE’

In wind tunnel experiment conducted Kyushu University

[1], two types of hollow structure models, a nozzle and a diffuser were tested. The experiments discovered that the wind tends to avoid the nozzle type model, while the wind was inhaled in diffuser t ype model. The diffuser shape structure accelerated the wind at the entrance and increased the mass flow rate as well. Then a ring -type plate, called „brim" was added to the exit periphery of the diffuser.

The plate formed vortices behind the diffuser creating a low pressure region. As the wind flows into a low pressure region, wind velocity was further accelerated near the entrance of the diffuser. Next an inlet shroud was added at the entrance to ease the wind flow. The collection acceleration device with a brim is Wind Lense.

III. COMPUTATIONAL METHOD

The free stream velocity considered is very less for this study; so 2D incompressible model has been employed for this analysis. The brimmed diffuser structure is shown in Figure 2. Fluent 6.3 was used as CFD solver for the analysis with Spalarat-Almaras one equation turbulence model and axisymmetric conditions. Spalarat-Almaras is a simple yet accurate model for analysis of turbulent flows. In order to treat the derivatives, second order upwind scheme has been us ed. All the analysis have been performed on Ansys 18.2.

This wind lense was designed for a rotor of diameter 1m with 0.1m and 0.22m diffuser width. The parameters were adopted from the experiments conducted by Yuji Ohya[1]. To make the analysis simple only the shroud is considered in CFD analysis. The height of the brim and the throat position was varied as a parameter.

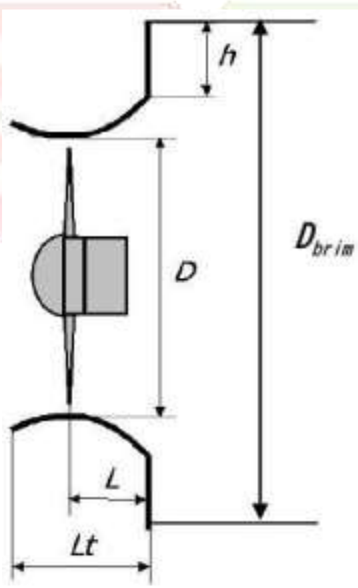


Figure : 2 Shape of Wind Lense

IV. PROJECT OBJECTIVES AND PARAMETERS

3.1 Effect of change in the position of venturi

The primary focus of the test is to measure and optimize the wind lense profile by changing the position of the throat. The throat was shifted at 0.2L, 0.5L and 0.7L from the brimmed end. Table 1 shows the details of the models generated based upon the parameters obtained by the research of Yuji Ohya [1]. Model 1, Model 2 and Model 3 have the same dimensions of throat diameter, length of the lense, brim height. Here D_e/D is the ratio of exit diameter to the throat diameter. L_t/D is the ratio of throat diameter to the Total Length of the Wind lense.

Description	Throat Position L/Lt	De/D	Lt/D
Model 1	0.2	1.138	0.1
Model 2	0.5	1.138	0.1
Model 3	0.7	1.138	0.1
Model 4	0.2	1.294	0.221
Model 5	0.5	1.294	0.221
Model 6	0.7	1.294	0.221

Table: 1 Parameters of Wind Lense Shape

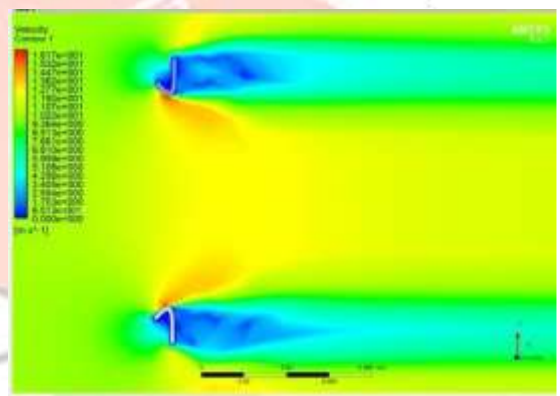


Figure : 3 Model 1

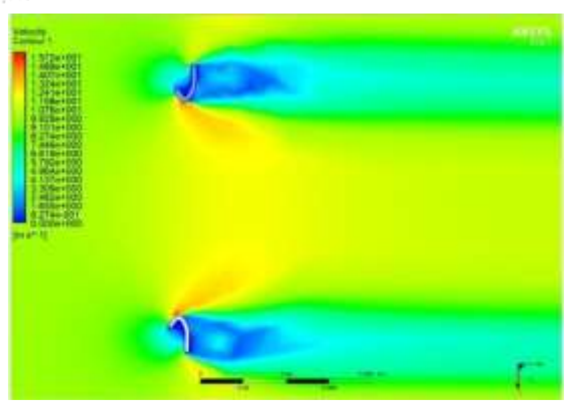


Figure : 4 Model 2

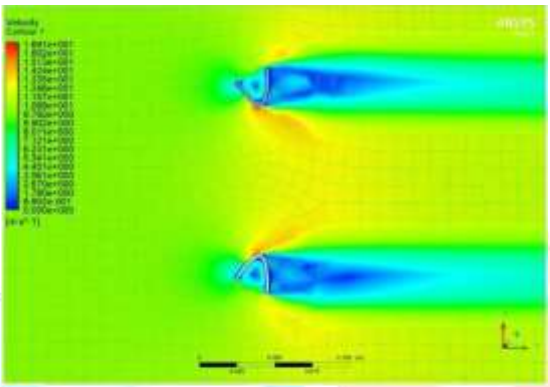


Figure : 6
Model 4

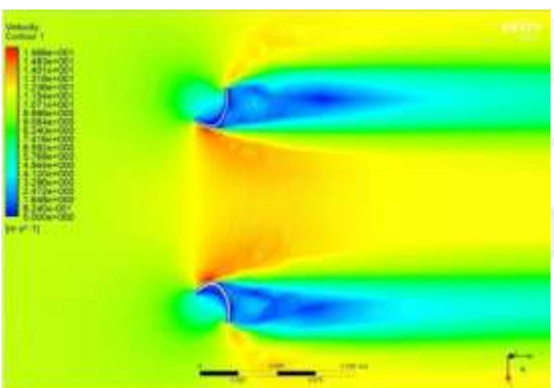


Figure : 7
Model 5

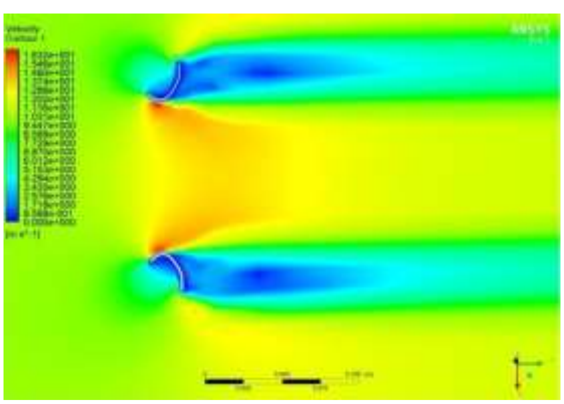
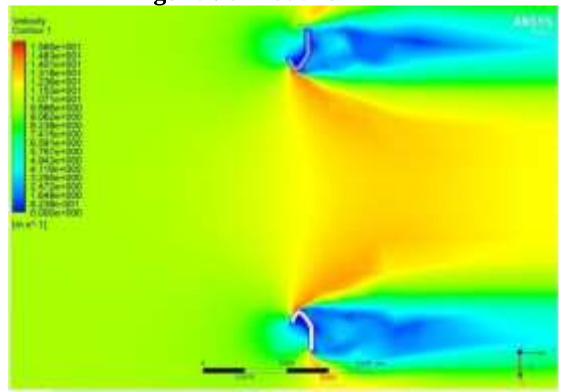
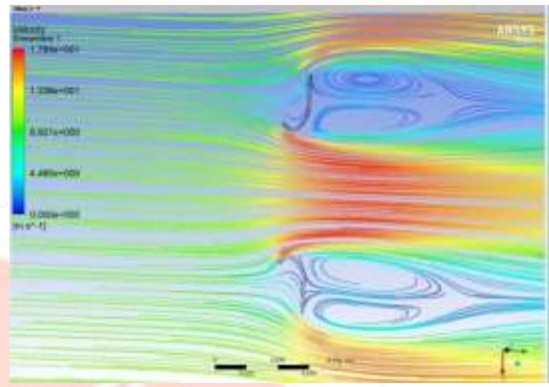


Figure : 8

Figure : 5 Model 3





Model 6

3.1 Effect of change in Brim height

Although the brim height, had been varied during several studies. In a research carried out by Srikanth K S and Tushar [2], the ratio of brim height to diffuser width was varied from 0 to 1 in increments of 0.2. In their research the power increase was found to be 1.5- 2 times without the brimmed diffuser i.e. wind lense.

Yuji Ohya [1] experimented with brim height as 10% of the throat diameter. In order to increase eddies formation and increase the induced vortex behind the brim, the area of the brim needed to be increased and hence the brim height was increased. The ratio of brim height to the throat diameter was considered as a parameter for study. This ratio was varied from 0.1 to 1.

Models which showed promising results in the previous test were considered for this study. Model 5 and Model 6 each were analyzed with six different brim heights, and results were tabulated.

Figure : 9 h=0.3D Model 5

Figure : 10 h=0.7D Model 5

Figure : 11 h=0.3D Model 6

V. RESULTS

While the dimension remained the same as well as the external parameters, only the change of throat position created a huge difference in the results obtained [Fig.3-8]. The extractive wind power for the turbine was found to increase by 3.83times. An increase in the wind velocity was found to be 1.44 times the inlet wind velocity. The results were tabulated in Table 2.

Considering the maximum velocity to be near the throat, Model 5 and Model 6 were selected for further study.

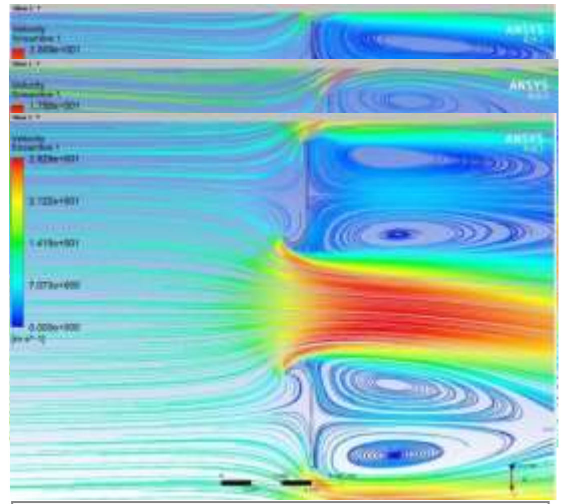
Model	Maximum Velocity (m/s)
Model 1	16.17
Model 2	15.72
Model 3	15.65
Model 4	16.91
Model 5	15.66
Model 6	16.32

Table:2 Results of Throat Position

The change of brim size produced more promising results as the maximum velocity around the lense was found to increase twice the inlet speed. As the brim height was increased the local wind velocity increased along with the intensity of the vortices behind the brim. After certain stage in both the models viz Model5 and Model6 the velocity decreased than the previous model. Table 3 shows the results of the maximum velocity around the wind lense at different brim height. Figure 13 and Figure 14 shows the trend of velocity against the brim size.

Description	Model 5	Model 6
h= 0.1D	15.66	16.32
h= 0.2D	17.52	17.23
h= 0.3D	17.84	17.88
h= 0.5D	21.58	21.72
h= 0.7D	28.09	28.29
h=D	17.92	24.25

Figure : 12 h=0.7D Model 6



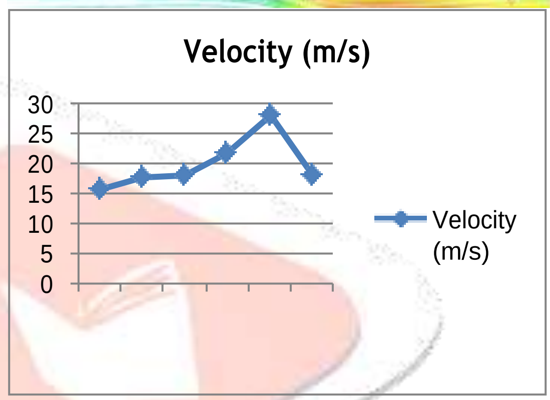


Table:3 Maximum Velocity at different brim height

Figure: 13 Velocity curve Model 5

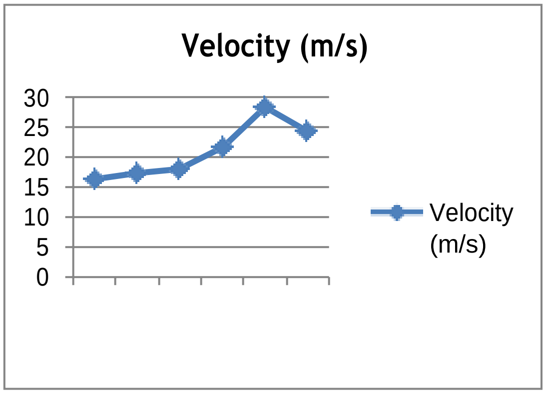


Figure : 14 Velocity curve Model 6

VI. CONCLUSION

Obstruction in the form of the brim increases flow through the diffuser and thus through the turbine rotor. It is seen that for the case with ratio of brim height to throat diameter of diffuser as 0.7, the maximum velocity is almost thrice that of stream velocity and average velocity is 1.82 times the stream velocity. From Betz equation we can conclude that the output from wind can increase 4-6 times the stream velocity. Considering the practical losses and friction the net output is expected to increase by 2-3 time the bare wind turbine output. The local increase in wind velocity allows the wind turbine to work at very low cut in speeds.

VII. REFERENCES

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